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THE ROLE OF CERTAIN NORTHERN MICHIGAN BOG MATS
IN MOSQUITO PRODUCTION

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THE ROLE OF CERTAIN NORTHERN MICHIGAN BOG MATS IN MOSQUITO PRODUCTION¹

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The data upon which this paper is based are the results of an investigation of the limnological role of bog mats in mosquito production. One of the characteristic features of bog lakes in the Great Lakes region is the occurrence of marginal mats which vary in kind and differ in extent through all degrees from small fringes to large conspicuous areas many acres in size. In their totality these mats in Northern Michigan cover many square miles. Since such mats overgrow the surface of the open water of bog lakes, they impound, both within and upon themselves, great quantities of water in such a way as to appear to provide unusually favorable conditions for mosquito breeding. However, popular opinion is conflicting on this point, some contending that they must be great breeding grounds and others insisting that mosquito larvae do not occur in these mats. Thus far, the writer has not found in the tremendous literature dealing with mosquitoes any paper which treats specifically with this problem. In this investigation the writer has attempted to evaluate certain kinds of bog mats as mosquito breeding grounds and to determine the limnological features of these areas in relation to mosquito life.

This study was begun in the summer of 1935 and continued throughout each succeeding spring and summer through 1939. Intensive field work was carried on during the spring and early summer since these periods were soon discovered to be particularly significant.

The writer is indebted to Professor Paul S. Welch under whose direction the work was done; to Professor Robert

Matheson for permission to work in the mosquito collection at Cornell University and for his verification of certain identifications.

SITUATIONS INVESTIGATED

Except for the included lakes, all waters of the bogs studied were shallow. No pools were found having a maximum depth greater than one meter. Most of them varied in depth from a few centimeters to about 0.3 meter. The bottoms of the pools were littered with decomposing leaves, twigs, and humus. Each pool commonly contained debris originating from the surrounding vegetation. Some of the pools contained large quantities of *Algae* and living *Sphagnum*. Most of the waters were strongly colored and highly turbid. All pools began to dry by evaporation as soon as the ice melted in the spring. This drying concentrated the aquatic life, the suspended matter, and probably some of the dissolved chemicals.

Mud Lake

The bog known locally as Mud Lake is located in Inverness Township, Cheboygan County, Michigan. Descriptions by Goe, Erickson and Woollett ('25), Jewell and Brown ('29), and Welch ('36a) make unnecessary any general account here. For present purposes it is desirable to point out that the lake is surrounded by a typical mat, grounded at the periphery and floating at its lake-ward edges; that this mat is narrow on one side of the lake and very extensive on the other; that most of the mat is either of the typical *Chamaedaphne-Sphagnum* type or of the *Carex* type; and that this great area of mat impounds extensive quantities of water.

¹ Contribution from the Biological Station and the Department of Zoology, University of Michigan.

Chamaedaphne-Sphagnum mat

This *Chamaedaphne-Sphagnum* mat, many acres in extent, holds its copious supply of water in two ways: (1) as exposed pools on the surface, (2) within the mat itself. The surface pools are formed in early spring by a combination of melting snow and spring rains. These pools are of two kinds, (1) larger pools, usually not shaded, with a maximum depth of about 30 cm., (2) smaller shaded pools varying in depth up to about 15 cm. Hundreds of these pools are scattered over the mat at this time of the year. Most of these smaller pools occur about the bases of various trees and shrubs.

Swamp pools

The numerous temporary swamp pools were deeply shaded and thus warmed slowly. They varied in depth from 5-80 cm., contained no green plants and gradually decreased in size until dry.

Some permanent swamp pools were found located at the bases of trees or stumps in holes which extended for some distance under the moss-covered roots and logs. The pools were small, in deep shade, cool; and generally of greater depth than the temporary ones.

Pools among aspens at bog margin

The soil beyond the swamp is of such coarse sand that water did not remain on the surface more than a few hours unless the spot was near the level of the lake. A few such pools were found at the margin where aspens and swamp meet. These were shallow, filled with leaves, exposed to the sun in early spring, and first in the area to dry.

Bryant's Bog

This bog is situated in close proximity to the southwest shore of Douglas Lake, Cheboygan County, Michigan. It has been the subject of many studies during the past 30 years. (For bibliography see

Welch, '36b.) Therefore, for the purposes of this paper it is necessary only to point out that the major portion of this bog is occupied by an extensive mat enclosing at its center a small remnant of the original open water. The mat is for the most part a mixture of sedges (*Carex lasiocarpa*), *Chamaedaphne calyculata* and sphagnum moss. Pools on the mat are similar to those at Mud Lake but the temporary pools at the margin between the aspens and the mat ("marginal ditch") are larger, deeper and persist longer during spring.

METHODS

The equipment used to collect larvae consisted of a water net (Matheson, '29, p. 79), white porcelain dippers of 2-4 quart capacity, a tea strainer, a strainer jar (Ward and Whipple, '18, p. 804) and collecting bottles. The strainer jar, as used, did not produce water currents strong enough to cause damage to the larvae. Adult collections were made by the use of an aspirator, an insect net, light traps, traps placed over the water to capture emerging adults, chloroform bottles, and a light hung before a white canvas.

All measurements of free carbon dioxide and carbonates were made as directed in Standard Methods for the Examination of Water and Sewage (8th ed.). Dissolved oxygen samples were analyzed by the use of a modification of the Rideal-Stewart method utilizing standard reagents as required for the Rideal-Stewart modification of the Winkler Method. Proportionate amounts of the reagents were added to the sample, which was 40 cc. in volume, by pipettes graduated to 0.01 cc. Twenty cc. of the prepared sample were titrated with 0.025 normal sodium thiosulfate which was diluted to ten times its volume. Since only 0.1 of a standard sample was titrated and the sodium thiosulfate was diluted ten times, the titration value was directly comparable to that of the standard method.

A quinhydrone electrometric instrument was used for all pH determinations.

The usual equipment for taking water samples could not be used because of the extremely varied conditions of the pools. Some pools were too shallow; others were so small that all the water had to be taken in order to secure a usable sample. Most pools were so filled with debris and organisms that sampling was a major problem.

A special sampler (figure 1), similar to Hale's Sampling Apparatus (Whipple, '27, p. 78), was constructed using a 40 cc. oxygen sample bottle and a 250 cc. overflow bottle, each capped with a close

fitting crutch tip to insure complete filling. Glass tubes were arranged as in Hale's Sampling Apparatus but an intake hose was fitted to the smaller bottle and a suction hose to the larger one. The bottles were then set in a metal support, the free end of the intake hose was placed in water, and by taking the end of the suction hose in the mouth and withdrawing the air both bottles were filled. The oxygen sample bottle was overflowed at least six times its own volume and all overflowed water was saved to test for carbonates, bicarbonates and conductivity.

A strainer (figure 2) was devised to separate the water from the debris. This

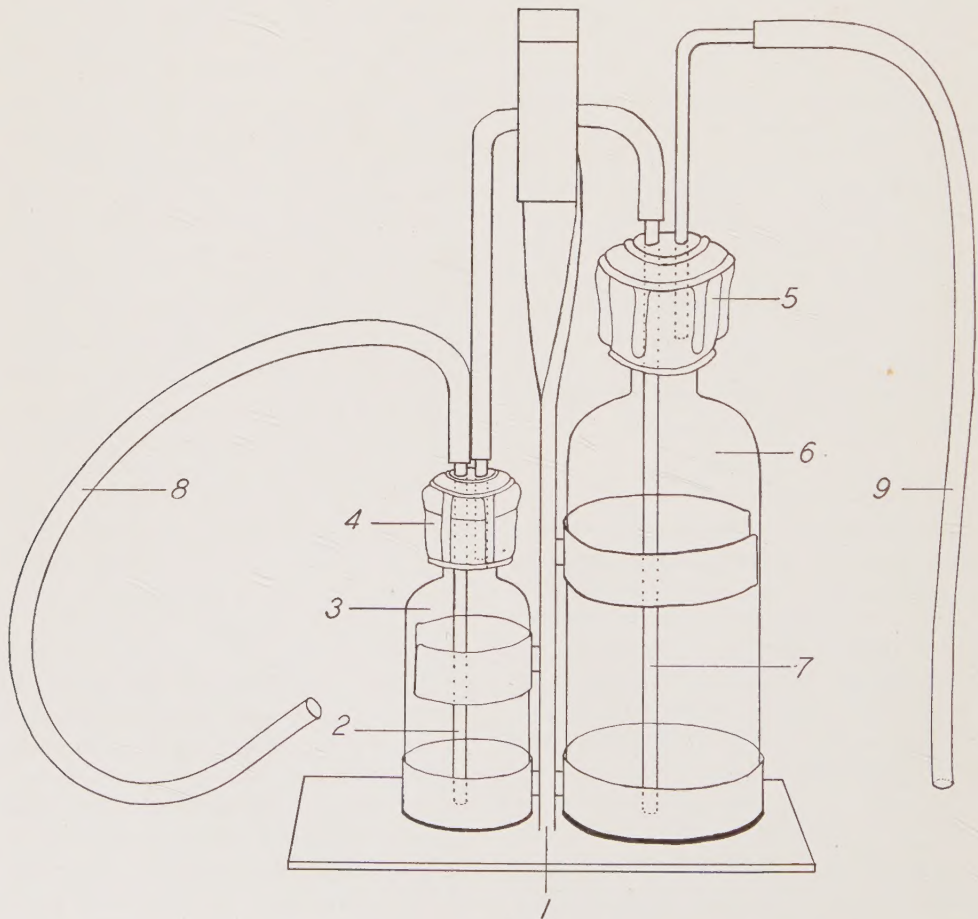


FIG. 1. Sampler as used in taking water samples for chemical analyses. 1, metal support; 2, glass tube; 3, 40 cc. sample bottle; 4, crutch tip; 5, crutch tip; 6, 250 cc. bottle; 7, glass tube; 8, intake hose; 9, suction hose.

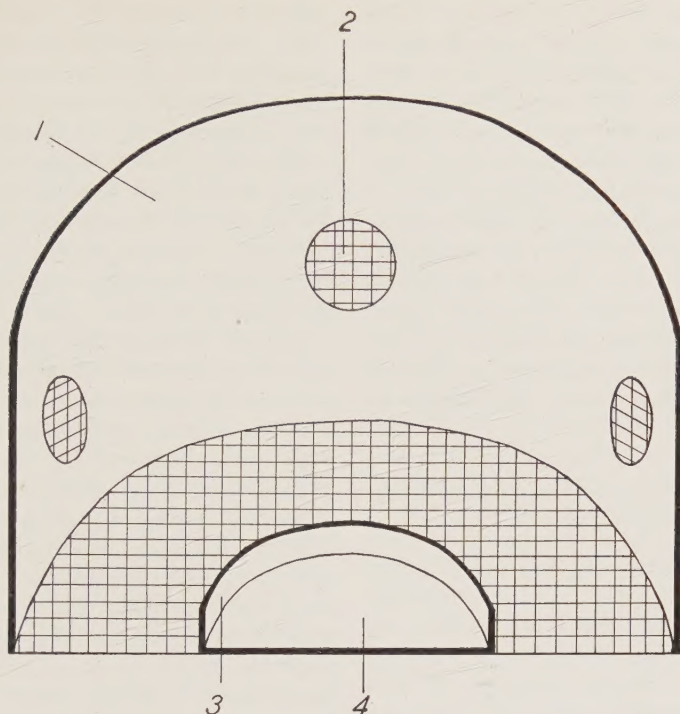


FIG. 2. Sectional view of the strainer used in excluding debris from water samples. 1, copper cylinder; 2, screened window; 3, flange at margin of central disc; 4, copper disc at central portion of bottom.

strainer consisted of a copper cylinder 5 cm. deep and 13 cm. in diameter, open at the top, patched with copper screen at intervals on the sides and covered with copper screen on the bottom except for the central portion. The central portion was a copper disk 5 cm. across with an 8 mm. vertical flange around its margin. The strainer was placed in a pool so the water could enter only through the screens. The end of the intake hose of the sampler was held directly above the disk while taking samples. Thus debris was excluded and strong currents prevented. With this equipment agitation of water was minimal and analyzable water samples were obtainable.

SEASONAL FEATURES

In spring most pools in which early breeding species grow are formed of

water from melting snow and ice. Larvae of several species of mosquitoes appear even before the ice is all gone. As there is a variation in time from year to year when melting takes place, there is a similar variation in the time of appearance of larvae. Larvae develop slowly when water is cold, but their rate of growth increases when the water is warmed. Irrespective of an early or late start, the last larvae of a given species were collected about the same date each year.

Pools exposed to the sun accumulate heat more rapidly than shaded pools and produce mature larvae first, also these pools are the first to cease mosquito production. Representatives of the same species may occur in both kinds of pools but in shaded ones, which remain cooler, larvae always mature at a later date. In shaded swamp pools, final emergence may

be as much as 4 to 6 weeks later than from pools exposed to the sun. Bryant's Bog area is less shaded but more protected from the wind than Mud Lake area. Consequently the water warms more rapidly and also begins and ends mosquito production at an earlier date.

The first mosquitoes to appear either as larvae or adults were representatives of the genus *Aedes*. Certain species of *Aedes* consistently came first with others arriving later in definite sequence. By the time most *Aedes* had emerged, larvae of *Anopheles* and *Culex* had begun to appear.

PHYSICO-CHEMICAL FEATURES OF BOG POOLS

The temperature of the pools varies with the time of year, kind of weather, time of day and depth of water. In early spring pools often freeze over at night. The following morning the ice melts and in shallow pools the temperature may rise as high as 20° centigrade only to be frozen again at night. Shallow pools warm more readily than the deeper ones. The surface and marginal water reaches a higher temperature during the day than the water of the deeper parts.

The waters of the bog pools had an acid reaction. This acidity varied from place to place within a pool as well as from pool to pool. For example, in a mat pool in which surface water had a pH of 6.9, another sample taken 5 cm. below the surface had a pH of 5.5 and a third sample taken 10 cm. below the surface had a pH of 5.0. Similar conditions were repeatedly found in various pools. There was also a variation in acidity from place to place within the same pool at equal depths. Rains always decrease the acidity of an acid pool. In general the waters of Bryant's Bog gave a more acid reaction than those of Mud Lake.

Most bog pools have a low oxygen content. Dissolved oxygen varies from time to time and place to place within a given

pool. Two factors causing these fluctuations are photosynthesis and rain, each increases the oxygen content; two others, decomposition and rise in temperature, tend to decrease it. A sample taken from a marginal pool at Bryant's Bog following a heavy rain had an O₂ content of 8.9 cc. per l. Deeply shaded pools contain few chlorophyll-bearing plants and as a result the oxygen content was, for the most part, 0.0 cc. per l.

Carbon dioxide likewise varies from time to time within each pool. Decomposition, photosynthesis and respiration of organisms are important factors causing these variations.

Phenolphthalein alkalinity was found to be 0.0 p.p.m. in all pools. Methyl orange alkalinity varied from time to time within each pool and also varied from pool to pool. Conductivity varied somewhat within the same pool and considerable from pool to pool, however, there was a tendency toward consistency for a given area. Shade was a variable factor among pools depending upon their positions. In wooded areas there is always some shade. If the trees were evergreens the shade was constant, but if deciduous there was generally little shade in early spring and often heavy shade when they became foliated. Many pools were in the open. The amount of shade controlled the water temperature to a large extent.

Physical Conditions of Drying Pools

Mosquito breeding bog pools are seldom constant in water volume. All tend to dry; some early in spring; others shortly after they are formed by rain. Many smaller pools are formed, by this drying, in the lower spots of what was the bottom of a large pool. Mosquito larvae experience numerous changes due to this reduction in water volume. As the water decreases larvae are crowded together resulting in increased competition for the food present in the decreased feeding area. The numerous predaceous

aquatic organisms are concentrated in like manner. In such situations mosquito larvae are increasingly less able to escape. The result is a high mortality from predators, lack of food, and lack of water. Then too, a higher temperature is reached in shallower water which may facilitate an attack of fungus that kills many larvae unless they transform promptly throwing off the fungus with the exuviae. Often pools dry completely before the larvae have transformed.

Some compensating features are present which tend to aid mosquito production in such situations. Larvae mature more rapidly in warmer waters. Some kinds of pupae can complete their development in less water than is necessary for the survival of their larvae. Pupae of the genus *Aedes* have been found transforming to adults in mud pools from which all water above the mud and leaves had vanished.

Since larvae must swim about in order to obtain food, they require some open water. *Aedes* larvae hang head-downward and thus require a minimum depth of water equal to their body length. Smaller larvae often inhabit shallower waters than do larger ones. This applies both to species whose larvae are small at maturity and to those large at maturity.

These conditions were found to exist wherever mosquito producing pools approach extinction. They were observed in pools at the edge of the aspens, in temporary swamp pools and in some sphagnum mat pools.

Mosquito Production of Various Kinds of Mats

Mosquitoes are produced wherever water stands on the mats in early spring. Production begins with the formation of pools and continues for some time. The length of this production period depends upon the following conditions: (1) existence of pools; (2) water temperature; (3) presence or absence of large filamentous algal growths; and (4) species

involved. If filamentous algal growths are abundant, most larvae are eliminated from pools since bottom feeding larvae must be able to swim through water. *Aedes* species begin their existence early while most other species appear somewhat later in spring (table VIII).

The larger mat pools and those bordering on the aspens were first both to produce adults and to cease production. They begin production earlier because of their rapid rise in temperature due to exposure to the sun. Pools at the margin of the aspens soon dry (at Mud Lake usually about the second week in May), thus preventing further mosquito production while larger mat pools cease *Aedes* production through total emergence. However, these pools generally dry up later in spite of the fact that the floating portions of the mats follow the declining water level of the lake. The smaller pools of the mat continue production of *Aedes* for a longer period since they are kept cool by shade. Swamp pools being deeply shaded, continue to produce *Aedes* for as much as 4-6 weeks longer than the others. It was from these cold swamp pools that the latest seasonal records of 4th instar *Aedes*

TABLE I. *Physico-chemical data from pools on Mud Lake, Sphagnum mat, 1938 and 1939*
l—large; s—small

Date	Type of pool	Water depth cm.	Temp. C.	pH	O ₂ cc. per l.	CO ₂ p.p.m.	M.O. Alk. p.p.m.	Cond. mho
1938								
4-30	l	60	9.5	5.6	1.5	1.9	0.0	42
5-14	l	45	18.0	5.5	1.5	2.7	20.0	42
5-28	l	45	16.5	5.2	3.3	1.8	0.0	47
6-26	l	15	21.0	4.8	0.7	1.5	0.0	70
7-11	l	7	15.0	5.8	0.0	4.5	35.0	95
7-26	l	7	20.0	5.1	0.1	2.1	6.0	95
8-8	l	15	19.0	5.0	0.0	4.8	20.0	80
8-21	l	10	21.0	5.9	0.5	3.0	32.0	..
8-23	l	0	23.5	4.9	0.0	9.2	25.0	..
1939								
5-13	l	22	26.0	5.9	4.7	7.5	0.0	155
5-13	s	15	26.0	6.1	1.0	19.5	0.0	95
5-30	l	10	30.0	5.2	3.3	11.0	0.0	250
5-30	s	10	18.0	4.9	0.0	35.0	3.0	82
6-19	l	7	26.0	5.3	0.6	45.0	7.0	65
6-19	s	15	17.0	5.2	0.0	36.0	12.0	45
7-10	s	10	18.0	4.8	3.5	17.5	0.0	105

larvae were obtained (table VIII). Although there is some difference in the physico-chemical features of *Chamaedaphne-Sphagnum* and *Carex* mat pools (tables I, II, III, V and VI), no outstanding difference in kinds of mosquitoes was found (table IV).

TABLE II. *Physico-chemical data from pools on south end of Mud Lake, Carex mat, 1938*
l—large; s—small

Date	Type of pool	Water depth cm.	Temp. C.	pH	O ₂ cc. per l.	CO ₂ p.p.m.	M.O. Alk. p.p.m.	Cond. mho
5-14	l	30	8.0	5.2	0.6	2.4	36.0	170
5-28	l	36	11.5	6.0	3.3	2.5	34.0	150
6-26	l	22	17.0	6.2	0.7	1.8	114.0	290
7-11	l	5	17.0	6.6	2.8	1.2	100.0	225

Sphagnum-mat pools were found to contain 21 species; *Carex*-mat pools, 17; swamp pools, 14; and pools at the margin of the aspens, 7. Some species occurred in more than one of these situations. All pools contained a total population of 27 different species. Certain species were taken from one situation only but in each instance the larvae were found in such small numbers that it is possible that they could also develop in other situations if given an opportunity.

At Bryant's Bog the mat pools contained 14 species; those at the margins of the aspens, 13. Since many of them inhabit both kinds of pools the total population consisted of only 18 species. There was a greater quantity of water in the pools at the edge of the aspens than on the mat. The deeper water took longer

TABLE III. *Physico-chemical data from pools in Mud Lake swamp, 1938*

Date	Water depth cm.	Temp. C.	pH	O ₂ cc. per l.	CO ₂ p.p.m.	M.O. Alk. p.p.m.	Cond. mho
5-14	60	8.0	5.0	0.0	1.5	20.0	55
5-28	60	11.5	5.2	0.6	1.9	0.0	82
6-26	45	14.5	5.0	0.4	2.9	21.0	85
7-11	30	15.0	5.8	0.0	2.5	35.0	95
7-26	30	16.0	5.1	0.0	2.1	14.0	65
8-8	15	17.0	5.5	0.0	1.8	25.0	82
8-21	15	18.0	5.2	0.0	2.7	2.6	..

TABLE IV. *Distribution of larvae in various types of bog pools*

	Mud Lake				Bryant's Bog	
	Sphagnum mat	Carex mat	Swamp	Margin of aspens	Sphagnum mat	Margin of aspens
<i>Aedes aurifer</i> (Coq.)	*	*	*	*	*	*
<i>Aedes canadensis</i> (Theo.)	*	*	*	*	*	*
<i>Aedes cinereus</i> Meigen	*	*	*	*	*	*
<i>Aedes communis</i> (DeGeer)	*	*	*	*	*	*
<i>Aedes dianthaeus</i> H., D. & K.	*	*	*	*	*	*
<i>Aedes excrucians</i> (Walker)	*	*	*	*	*	*
<i>Aedes fitchii</i> (F. & Y.)	*	*	*	*	*	*
<i>Aedes impiger</i> (Walker)	*	*	*	*	*	*
<i>Aedes implacabilis</i> (Walker)	*	*	*	*	*	*
<i>Aedes intrudens</i> Dyar	*	*	*	*	*	*
<i>Aedes lateralis</i> (Meigen)	*	*	*	*	*	*
<i>Aedes pullatus</i> (Coq.)	*	*	*	*	*	*
<i>Aedes punctor</i> (Kirby)	*	*	*	*	*	*
<i>Aedes spenceri</i> (Theob.)	*	*	*	*	*	*
<i>Aedes sticticus</i> (Meigen)	*	*	*	*	*	*
<i>Aedes stimulans</i> (Walker)	*	*	*	*	*	*
<i>Aedes trichurus</i> (Dyar)	*	*	*	*	*	*
<i>Aedes vexans</i> (Meigen)	*	*	*	*	*	*
<i>Anopheles maculipennis</i> Meigen	*	*	*	*	*	*
<i>Anopheles punctipennis</i> (Say)	*	*	*	*	*	*
<i>Culex apicalis</i> Adams	*	*	*	*	*	*
<i>Culex pipiens</i> Linnaeus	*	*	*	*	*	*
<i>Culex restuans</i> Theob.	*	*	*	*	*	*
<i>Theobaldia impatiens</i> (Walker)	*	*	*	*	*	*
<i>Theobaldia inornata</i> (Willis.)	*	*	*	*	*	*
<i>Theobaldia morsitans</i> (Theob.)	*	*	*	*	*	*
<i>Wyeomyia smithii</i> (Coquillett)	*	*	*	*	*	*

to dry up leaving the pools in existence until after the *Aedes* had emerged. Since all pools at Bryant's Bog are more exposed to the sun and more protected from the wind than is the general situation at Mud Lake, larvae matured earlier and ceased their production at an earlier date.

Although the two bogs exhibit considerable differences in some of the physico-chemical features (tables I, II, III, V and VI), in general the same kinds of mosquitoes were found in both (table IV), most exceptions being species whose members were taken in very small numbers. *Aedes aurifer*, *A. fitchii*, *A. impiger*, *A. pullatus*, *A. sticticus*, *A. stimulans*, *Culex pipiens*, *Theobaldia impatiens* and *T. inornata* were sparsely represented at Mud Lake and did not occur at Bryant's Bog. *Theobaldia morsitans*, common at Mud Lake, was absent at Bryant's Bog. *Aedes intrudens*, abundant in the pools at the margins of the

TABLE V. *Physico-chemical data from pools on Bryant's Bog, Sphagnum mat, 1938*
l—large; s—small

Date	Type of pool	Water depth cm.	Temp. C.	pH	O ₂ cc. per l.	CO ₂ p.p.m.	M.O. Alk. p.p.m.	Cond. mho
4-30	l	30	16.0	4.0	3.4	2.4	0.0	60
5-14	l	45	18.0	4.2	4.2	..	15.0	40
5-29	l	15	21.0	4.3	0.0	3.0	0.0	95
5-29	s	21	19.5	4.0	2.4	4.0	0.0	80

TABLE VI. *Physico-chemical data from pools at Bryant's Bog among aspens, 1938*

Date	Water depth cm.	Temp. C.	pH	O ₂ cc. per l.	CO ₂ p.p.m.	M.O. Alk. p.p.m.	Cond. mho
4-30	90	12.5	4.2	2.3	3.0	0.0	37
5-14	90	14.0	4.7	8.9	2.8	48.0	65
5-29	90	18.0	5.8	0.0	3.5	25.0	45

aspens at Bryant's Bog, was not found at Mud Lake. However, it is of interest to note this species did not occur at Bryant's Bog in 1937. Species of *Anopheles*, *Culex* and *Theobaldia* may occur in any pool which persists until late spring or into summer.

Mosquito Production Within the Mats

In addition to the pools, the mats of both Mud Lake and Bryant's Bog contain a great amount of water. Mud Lake mat is extremely wet. It is saturated to the extent that in large areas it appears flocculent. When one steps on these portions the mat will sink until the water reaches half way to the knees, but as one moves on the vegetation rises again to the water level. For physico-chemical data see table VII. It has been assumed that mosquitoes breed in such situations. The waters of these mats were sampled repeatedly for larvae by the following methods: (1) hollows were stamped in the mat and the water dipped and examined for larvae; (2) the vegetation was spread with two spades and the water inspected; (3) holes were dug and the inflowing water carefully examined; (4)

TABLE VII. *Physico-chemical data of water within Mud Lake Sphagnum mat, 1939 **

Date	Temp. C.	pH	O ₂ cc. per l.	CO ₂ p.p.m.	M.O. Alk. p.p.m.	Cond. mho
6-27	24.5	3.9	0.0	45.0	0.0	90
6-27	21.5	3.9	0.0	55.0	0.0	100
6-27	21.5	3.9	0.0	45.0	0.0	65
7-31	30.5	3.8	0.0	125.0	0.0	160
7-31	26.0	3.8	0.0	125.0	0.0	275
7-31	27.0	3.5	0.0	115.0	0.0	150

* Unpublished data furnished by Professor P. S. Welch.

sections of the mat were cut out and the vegetation washed bit by bit in a tub of clear water; and (5) during the summer of 1936 and during the entire mosquito breeding season from April 24 until August 16, 1937, four screened traps, each 2 feet square were placed over the mat and observed for emerging adults.

No larvae were found in the water nor were any adults that came from these waters taken in the traps.

Water from the mat was taken to the laboratory and immature larvae of *Culex restuans* and *C. apicalis* placed in it. The larvae matured, pupated and adults emerged, showing there was sufficient food present to support larval growth of these species.

A small section of the mat was taken to the laboratory and placed in a battery jar containing water and *Culex restuans* and *C. apicalis* larvae to see if the larvae could work through the vegetation. The mat vegetation was placed on the top of the water and pressed down into the jar until conditions simulated those in the mat in nature, with water coming to the upper surface of the vegetation. The contents of the jar were then observed for growth and movement of larvae. Under these conditions the larvae were unable to swim about either for food or to rise to the surface for air. The result was the death of all larvae. No larvae pupated and no adults emerged.

From these observations it appears that mosquito larvae need water sufficiently free from plants and debris to enable

them to swim about. Mosquitoes do not and cannot breed in the water within the mats because they are unable to swim about in search of food and air. This is not true in the smaller pools on the surface where a small amount of open water is present. Mosquitoes need open water at least as deep as their body length, of enough volume to produce sufficient food, and water that remains open long enough for their larval development. Since water within the mats lacks these features, mosquitoes are excluded from it.

Since the formation of mosquito breeding pools is dependent on depressions which hold water, bog situations should continue their production, year after year, regardless of the stage reached in lake-swamp succession provided water continued to become impounded on their surfaces.

Influences of Physico-Chemical Features on Larvae

Of the physico-chemical factors operative in these bogs, temperature seems to be the most influential in the processes of mosquito production. Most *Aedes* larvae occur in water cooler than that inhabited by *Culex*, *Anopheles* or *Theobaldia*. Species of *Aedes* having but one annual brood develop over a longer period in cold swamp pools than in waters that warm more quickly. A rise in water temperature increased the rate of development. Variations in pH within these areas showed little effect on larval occurrence. Fluctuations within a single pool were at times as great as the total variation among all pools. With one or two exceptions oxygen variations were as great in one area as in another. Carbon dioxide variations were generally as great within one pool as over the whole area. Shade appeared to have little control except as it influenced temperature and evaporation.

Evidently these features must have a wider range of variation than was found in areas studied if they are to constitute

limiting factors for the species represented. Many of these larvae inhabit waters subject to the following changes: temperature, 0°–20° C. within a 24 hour period; pH, near neutrality at the surface to 5.0, or even higher acidity, at the bottom; CO₂, O₂, and methyl orange alkalinity, wide variations from hour to hour.

SPECIES SUCCESSION

Table VIII represents the time of the year during which fourth instar larvae were found, excepting *Anopheles* in which case larvae of all ages are represented. Each horizontal line begins at the time when the species was first found and its termination indicates the date when the last specimens were taken. The triangle on the line indicates the time at which the larvae were the most numerous. It will be noted that the larvae of certain species consistently mature at an earlier date than others. Group 1, consisting of *Aedes canadensis*, *A. communis*, *A. dian-taeus*, *A. excrucians*, *A. implacabilis*, *A. intrudens*, *A. punctor*, and *A. trichurus*, first reached maturity during the last third of April and was most abundant on or before the middle of May. Group 2, composed of *Aedes cinereus*, *A. fitchii*, *A. impiger*, *A. lateralis*, *A. stimulans*, *A. vexans*, and *Theobaldia morsitans*, had its initial appearance during the first week of May and its peak of abundance very little later than that of Group 1. Group 3, which includes *Aedes aurifer*, *A. pul-latus*, *A. spenceri*, and *A. sticticus*, was found to have reached the fourth instar stage a few days following the first appearance of the members of Group 2. Since the species of Group 3 were taken only in small numbers, this may not represent the entire time of normal development. Group 4, composed of *Anopheles maculipennis*, *Culex apicalis*, and *C. restuans*, made its first appearance about ten days later than Group 3. The earliest records of members of this group being about May 20. *Anopheles punctipennis* larvae were first found about the first of

TABLE VIII. Occurrence of 4th instar larvae in pools of Mud Lake and of Bryant's Bog, 1937, 1938 and 1939

	April	May	June	July	August
<i>Aedes aurifer</i>		△			
<i>Aedes canadensis</i>		△			
<i>Aedes cinereus</i>		△			
<i>Aedes communis</i>		△			
<i>Aedes diantaeus</i>		△			
<i>Aedes excrucians</i>		△			
<i>Aedes fitchii</i>		△			
<i>Aedes impiger</i>		△			
<i>Aedes implacabilis</i>		△			
<i>Aedes intrudens</i>		△			
<i>Aedes lateralis</i>		△			
<i>Aedes pullatus</i>		△			
<i>Aedes punctor</i>		△			
<i>Aedes spenceri</i>		△			
<i>Aedes sticticus</i>		△			
<i>Aedes stimulans</i>		△			
<i>Aedes trichurus</i>		△			
<i>Aedes vexans</i>		△			
<i>Anopheles maculipennis*</i>					△
<i>Anopheles punctipennis*</i>					△
<i>Culex apicalis</i>			△		
<i>Culex pipiens</i>				△	
<i>Culex restuans</i>				△	
<i>Theobaldia impatiens</i>			△		
<i>Theobaldia inornata</i>			△		
<i>Theobaldia morsitans</i>			△		
<i>Wyeomyia smithii</i>					

* Larvae of all ages included.

June. Still another group, *Culex pipiens*, *Theobaldia impatiens*, and *T. inornata*, appeared later in the summer, but their infrequent appearance in collections makes the general maturing date somewhat questionable.

The first collections in 1938 were on earlier dates than those in 1937, due to seasonal variations of weather. However, the dates of their final collections

for each year were about the same regardless of early weather variations. Three species, *Aedes canadensis*, *A. cinereus*, and *A. punctor*, were found to have a longer period over which development may occur.

Table IX shows the dates when adults were first found in the areas. The extreme left end of the line represents the date on which the first adults of a given

TABLE IX. Occurrence of adult mosquitoes, 1937, 1938 and 1939

	April	May	June	July	August
<i>Aedes aboriginis</i>		—			
<i>Aedes aurifer</i>		—			
<i>Aedes canadensis</i>		—			
<i>Aedes cinereus</i>		—			
<i>Aedes communis</i>		—			
<i>Aedes dianiaetus</i>			—		
<i>Aedes excrucians</i>		—			
<i>Aedes fitchii</i>		—			
<i>Aedes implacabilis</i>		—			
<i>Aedes intrudens</i>		—			
<i>Aedes lateralis</i>		—			
<i>Aedes pullatus</i>		—			
<i>Aedes punctor</i>		—			
<i>Aedes riparius</i>		—			
<i>Aedes spenceri</i>				—	
<i>Aedes sticticus</i>		—			
<i>Aedes stimulans</i>		—			
<i>Aedes trichurus</i>		—			
<i>Aedes vexans</i>		—			
<i>Anopheles maculipennis</i>				—	
<i>Anopheles punctipennis</i>					—
<i>Anopheles walkeri</i>					
<i>Culex apicalis</i>			—		
<i>Culex pipiens</i>			—		
<i>Culex restuans</i>				—	
<i>Mansonia perturbans</i>			—		
<i>Theobaldia impatiens</i>					—
<i>Theobaldia inornata</i>			—		
<i>Theobaldia morsitans</i>			—		
<i>Wyeomyia smithii</i>		—	—		

species were collected. Since specimens of *Aedes dianiaetus*, *A. spenceri*, *Anopheles walkeri*, *Culex pipiens*, *Theobaldia impatiens*, and *T. inornata* were taken in small numbers, this table does not necessarily represent the earliest dates of their emergence. For example, larvae of *Aedes spenceri* were found maturing during the middle of May but the earliest collection of adults was about the middle of July. In this case adults were undoubtedly available for some time before they were found. Both larval and adult collections show the existence of a succession of species.

SUMMARY

1. In this paper are presented the results of an investigation of the limnological role of certain kinds of bog mats in mosquito production.
2. A water sampler and a strainer were devised to obtain water samples from

small, shallow pools containing large quantities of debris.

3. Bog mats that impound water upon their surfaces are habitats for mosquitoes at some time during each year.
4. Mosquitoes do not breed in the water *within* the mats since the interstices are too small to meet the minimal space requirement of the larvae.
5. Mosquitoes which breed *upon* the mats show a type of definite seasonal succession.
6. Gradual decrease in size of pools by drying is a regular event in spring and results in increasing concentration of mosquito larvae and aquatic predators, gradual reduction of feeding areas, increasing temperature and shrinking water supply. The end result of drying is disappearance of pools and termination of mosquito production. The regular spring disappearance of most pools on a *Sphagnum* mat explains the almost complete

absence, throughout the summer, of breeding mosquitoes from such a mat.

7. Mosquitoes which breed upon these mats do not appear to be influenced directly in any important way by variations of the chemical features of the impounded water.

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